Electronic Supplementary Material (ESI) for Environmental Science: Water Research & Technology

Electronic Supplementary Information (ESI)

Economic Analysis of Decentralized Water Reuse Systems in Mission Critical Buildings at U.S. Army Installations

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Section S1. Cost Functions of Water Reuse Systems at Different Design Scale

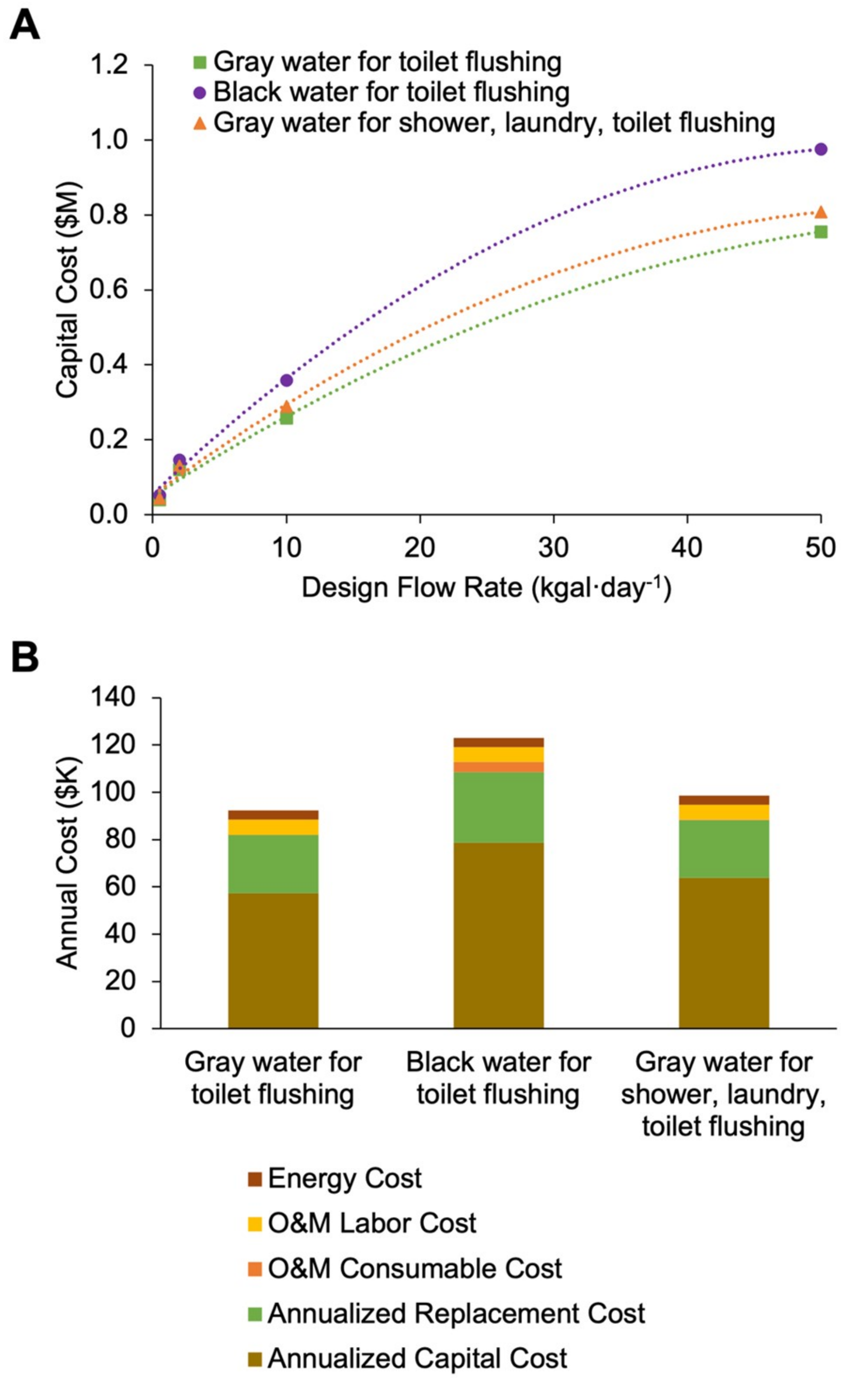

Figure ESI-1. (A) Capital cost curve of decentralized water reuse systems at different design flow rate. Green square = Gray water for toilet flushing. Purple circle = Black water for toilet flushing. Orange triangle = Gray water for shower, laundry, and toilet flushing. (B) Annualized water reuse system (28.2 kgal·day^{-1}) costs with 15 years system life and 6% discount rate.

Section S2. Determination of Economic Benefit

S2.1 Life Cycle Cost

The life cycle cost of system can be calculated as follows:

$$LCC = C_{Capital} + \sum_{i=1}^{n} C_{Recurring} \times \left[\frac{1}{(1+d)^n}\right]$$

(Equation S1)

where LCC is the life cycle cost in present value ($), $C_{Capital}$ is the capital cost ($), $C_{Recurring}$ is the recurring costs for operation and maintenance ($·year^{-1}), d is the discount rate, and n is the number of years between the base date and the occurrence of the cost.

S.2.2 Cost Savings

The cost savings associated with water demand offset can be calculated as follows:

$$C_{Saving} = P_{Water} \times \sum_{i=1}^{n} D_{Water\ Saving} \times \left[\frac{1}{(1+d)^n}\right]$$

(Equation S2)

where C_{Saving} is the cost saving in present value ($), P_{Water} is the unit price of water ($·kgal^{-1}), $D_{Water\ Saving}$ is the annual water demand offset (kgal·year^{-1}), d is the discount rate, and n is the number of years between the base date and the occurrence of the cost.

S.2.3 Net Savings

The net savings ($) is the difference between water cost savings and life cycle cost of system in present value and can be computed as follows:

$$Net\ Savings = C_{Savings} - LCC$$

(Equation S3)

S.2.4 Return on Investment

The return on investment (ROI) of system can be computed as follows:

$$ROI = \frac{Net\ Savings}{LCC} \times 100$$

(Equation S4)

where, ROI is the return on investment of system (%), $Net\ Savings$ is the difference between water cost savings and life cycle cost of system ($), and LCC is the life cycle cost of system ($).

Section S3. Uncertainty Modeling and Calculations

S3.1 Assumption for Uncertain Parameter

Table ESI-1. Assumptions associated with each of water reuse scenario at mission critical facilities along with values and citations thereof.

Assumption	Value	Citation
General		
Treatment system water recovery rate (%)	70	-
Capital cost upper range ($)	15% from baseline	-
Capital cost lower range ($)	-15% from baseline	-
O&M costs upper range ($)	15% from baseline	-
O&M costs lower range ($)	-15% from baseline	-
Number of Monte Carlo simulations (n)	1000	-
Water reuse for shower, laundry, and toilet flushing at a barracks building		
Water unit price ($·kgal^{-1})	Triangular (8.5, 10,12)	[1]
Electricity price ($·kWh^{-1})	Norm (0.15, 0.011)	[2]
Water demand (kgal·day^{-1})	Triangular (28.2, 33.9, 39.5)	[3–5]
Discount rate	Triangular (0.04, 0.06, 0.07)	[6,7]
Membrane replacement period (years)	Triangular (8, 10, 11)	-
Capital cost ($)	Dependent on building water demand	Vendor quote [8,9]
O&M costs ($·year^{-1})	Dependent on building water demand	Vendor quote [8,9]
Water reuse for server cooling at a data center		
Blowdown	30%	[10]
Water unit price ($·kgal^{-1})	Triangular (8.5, 10,12)	[1]
Electricity price ($·kWh^{-1})	Norm (0.15, 0.011)	[2]
Water demand (kgal·day^{-1})	Triangular (88.2, 98, 107.8)	[3,11]
Discount rate	Triangular (0.04, 0.06, 0.07)	[6,7]
Membrane replacement period (years)	Triangular (8, 10, 11)	-
Capital cost ($)	Dependent on building water demand	Vendor quote [8,9]
O&M costs ($·year^{-1})	Dependent on building water demand	Vendor quote [8,9]

S.3.2 Spearman's Rank Correlation Coefficient

$$\rho = 1 - \frac{6\sum_{i=1}^{n}[R(x_i) - R(y_i)]^2}{n(n^2 - 1)}$$

(Equation S5)

where ρ is the Spearman's rank correlation coefficient, n is the number of Monte Carlo simulations, x_i is the value of an uncertain parameter in simulation i, y_i is the output (system return on investment) for simulation i, and $R(\cdot)$ is the relative rank of x_i and y_i across the n simulations.

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